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Green Energy Fed High Speed Switched Reluctance Motor with Modified C-dump Converter

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Abstract: ***Switched reluctance motor is in its leading application path because of the low cost, reliability and high speed. This paper proposes a new topology of converter for switched reluctance motor. The world is seeking for green energy technologies for different applications. This paper presents the modified C-dump converter for switched reluctance motor. This is fed from a green source. Here the 26 v solar cell is used for the power supply. The dc-dc converter convert the 26 volt to 380v and that voltage is converted to ac by c-dump converter. The dc-dc converter is a boost converter based on two inductor method. Two Inductor Boost Converter is used in this paper. The SR motor is bifillar wounded and that converter is only for this type of Sr motor. The simulations are done on MatLab simulink and the results are in the paper.***

Keywords: SR motor, 26v solar cell, TIBC, bifilar winding, C-dump converter

1. Introduction

In the world there is increase in energy crisis due to increased consumption of energy, globalization. The new technologies are indeed now in the world, which can decrease the consumption of energy in the equipments. In the case of machines, the power consumption can de decreased in the converter by reducing the switches or making the motor at high speeds. The power, that is necessary for the motor, can be developed through green energy, which can be solar, chemical, wind etc. in this paper a dc-dc converter is presented that can convert 26V from a solar panel to 380V. This converter is based on Two Inductor which is known as Two Inductor Boost converter.

This paper also describe about the converter, modified C-dump converter, which uses for the bifilar winding switched reluctance motor. There are many topologies of converter are present. But this converter at its proper arrangements can increase the speed of the motor. In the modified C-dump converter the energy in the motor phases is partially diverted to the dump capacitor.

The design of a motor drive system powered directly from a photovoltaic source demands creative solutions to face the challenge of operating under variable power restrictions and still maximize the energy produced by the module. The output voltage should be same at all time. These requirements demand the use of a converter with the following features: high efficiency – due to the low energy available; low cost – to enable its deployment where it is most needed; autonomous operation – no specific training needed to operate the system; robustness –minimum amount of maintenance possible; and high life span – comparable to the usable life of 20 years of a PV panel.

2. Proposed DC-DC Converter

In the proposed system there uses a single PV module in order to ensure the low cost and accessibility. The converter should be able to drive the proposed system. Fig. 2.1 shows the proposed Two Inductor Boost converter (TIBC). The energy produced by the panel is fed to the motor through two converters: a DC/DC TIBC stage to boost the voltage of the panels and a DC/AC three-phase inverter to convert the DC voltage to three-phase AC voltage. The inverter is based on the modified C-dump technology which can connect to a bifilar wounded SRM. This topology needs further analyses. To verify the proposed system, a careful selection of the VSI components is necessary to guarantee the efficiency and cost requirements.

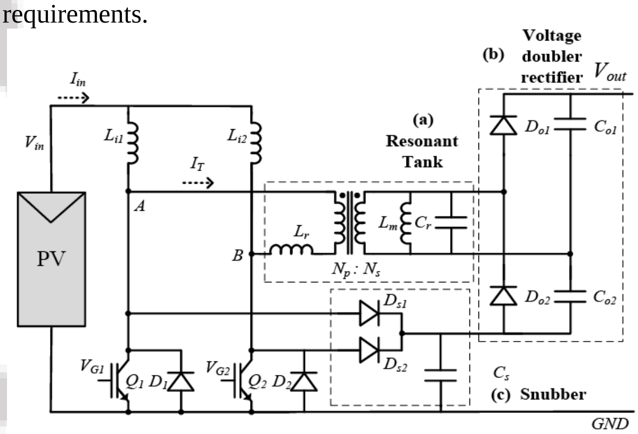

Figure 2.1: TIBC converter

To ensure the proper output at the proposed TIBC, a large voltage conversion ratio is needed. This is because of the low voltage characteristic of the PV panels and small input current ripple. So there will not be any oscillation over the maximum power point (MPP) and thus ensure the maximum utilization of the available power.

The proposed converter is under the current-fed topology. Current-fed converters have some advantages, when compared to the voltage-fed topologies. Mainly they have an inductor at the input so the system can be made to have input current ripple as low as needed, thus can eliminate the need of the input capacitor at the input voltage. Current-fed converters have an inherent high step up voltage ratio because they are normally derived from the boost converter, and so the transformer turns ratio can be reduced. Current-fed push-pull converter, the current-fed full-bridge and the dual half-bridge converter are of the same kind of topology. The drawbacks of the current fed topologies are with high voltage spikes created due to the leakage inductance of the transformers, and high voltage stress on the rectifying diodes. Implementation of zero voltage switching (ZVS) condition to the active switches or achieve zero current switching (ZCS) can take over the above problem.

3. Operation Principle

There are three modes of operation in TIBC. Either two switches are ON or only one switch is ON and the last stage is that the two switches are closed. In switching operation of the TIBC, the two switches Q_1 and Q_2 operates. L_{i1} and L_{i2} are charged by the input energy, when both Q_1 and Q_2 are turned on. When Q_1 (Q_2) is opened the energy stored in L_{i1} (L_{i2}) is transferred to C_{o1} (C_{o2}) through the transformer and the rectifier diode D_{o1} (D_{o2}).

When multi-resonant tank is introduced to system, two different resonant processes occur: 1) when the two switches are closed the Lr and Cr helps the circuit to achieve the ZCS. 2) during the conduction time interval that is t4 and t5 are ON, when at least one of the switches is open, Lr is in series with $Li1$ or $Li2$, not participating on the transformer's secondary current resonance.

At time t_1, the rectifying diode D_{o1} is already conducting. The voltage on resonant capacitor C_r is clamped at $+V_{out}/2$. At this instant, the switch Q_1 is activated.. As the switch is turned on, its voltage drops to zero, and the snubber diode D_{s1} is stop conducting. From t_1 to t_2, C_r transfer its energy to the leakage inductance L_r, beginning the primary switch's resonant process and forcing the current I_{Q2} on the switch Q_2 to decrease.

At the time t_2, D_{o1} stops conducting and C_r continues to resonate with the inductance L_m. From t_2 to t_3, the primary switch's resonance (Q_2) continues to force its current to decrease until it reverses its polarity. When I_{Q2} is negative, the switch can be turned off. This happens at instant t_3 when V_{gQ2} forced to zero.

At the time t_3 the voltage V_{dsQ2} starts to increase and Q_2 is completely OFF, the diode D_{s2} begins to conduct, transferring energy to the capacitor C_s. Between t_3 and t_4 C_r and L_m continue to resonate, decreasing the voltage on the rectifier's input. At instant t_4, the voltage across C_r reaches -V_{out} /2 and the rectifying diode D_{o2} starts to conduct, clamping V_{Cr} in -V_{out}/2.

From t_4 to t_5, the capacitor C_{o1} is charged, and the current of D_{o2} starts to decrease. At the instant t_5, Q_2 is turned on, starting the resonant process on Q_1. As Q_2 is activated, D_{s2} is forced to stop conduction. At t_6, the current in D_{o2} reaches zero, and D_{o2} stops conducting, reinitiating the resonance between C_r and L_m. From this moment until the end of the switching period, the process repeats symmetrically as explained for the other input switch.

4. DC-DC Boost Converter Simulation

The proposed converter was simulated on MatLab simulink. The system is in closed loop. Whenever the output level increases the two switches are made OFF. And when the output level decreases the two switches are made ON. With this arrangement in closed loop the converter output is made almost constant.

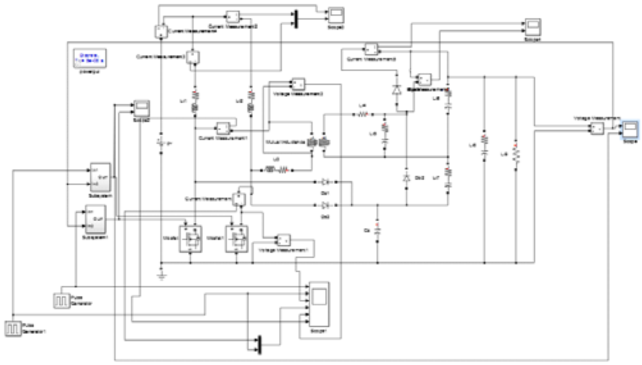

Figure 4.1: MatLab Circuit of TIBC

Fig. 4.1 shows the closed loop control system with the proposed converter. The current at the two inductors and the PV module is shown in the fig. 4.2. It is observed that each one of the inductors has a current ripple at the converter switching frequency and out of phase with each other, however both currents are supplied by the PV module and when they are analyzed together (I_{PV}) it is seen a reduction in the ripple amplitude to half of the original ones.

The fig. 4.3 describe about the zero current switching. The two pulses to the primary switches are also shown in the figure. The voltage across the switch and the current across the primary of the transformer are shown in the figure. The current in the primary winding of the transformer is shown in the same figure.

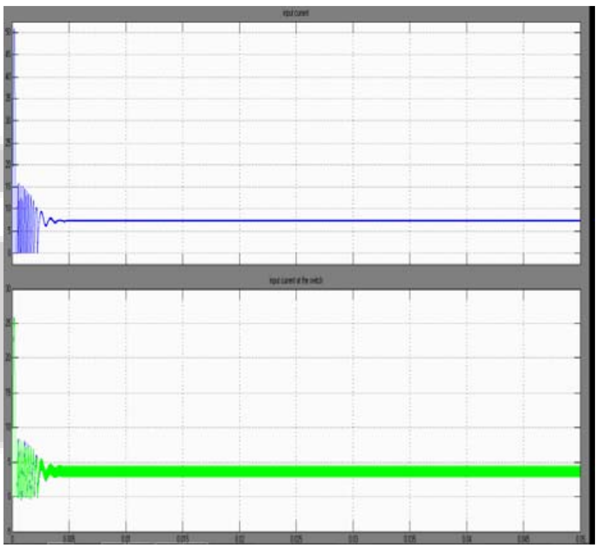

Figure 4.2: input currents to TIBC

The pulses are of continuous because it is taken directly from pulse generators. When closed loop comes in active the pulse wave for will change. There will be conditions of continuous pulse, there will not be any pulse and also spited pulse wave form. The zero current switching is clear in the waveform. It can see that when current in the switch comes to zero, the conduction stops and the switch made OFF.

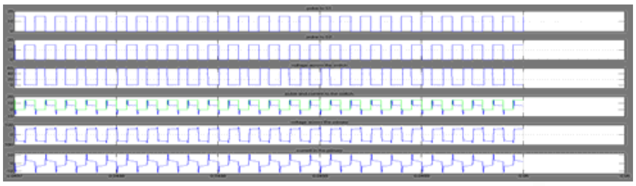

Figure 4.3: zero current switching

Fig. 4.4 shows the output current and the voltage. It can see that the voltage is increased to a higher level upto 380V.

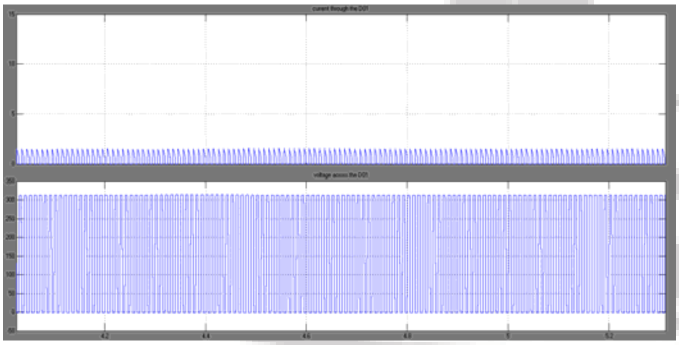

Figure 4.4: output from TIBC

The operation under ZCS condition allows the use of fast recovery diodes, thus reducing the total cost of the system. The fig. 4.5 shows the effect of closed loop system. The output voltage is first increasing above the required level at that time the pulse generator will not give pulse to the switches and so the output decreases. Then the voltage reduced below the required level so the switches conducting and the voltage increases.

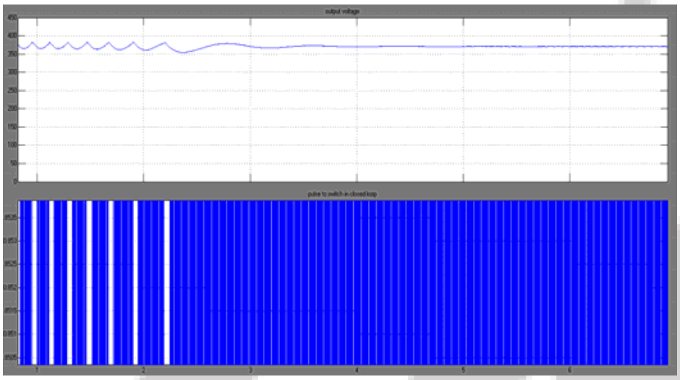

Figure 4.5: closed loop output of TIBC

Like this there is an oscillation at last reaches the required level of voltage.

4.1 SRM Converters

The drive circuit is an essential part of switched reluctance motors in order to operate properly. Nowadays, there are different topologies for drive circuits are available. There are researches are going on to run fast the motor with less components. One of these converter topologies is called C-dump converter. In this topology the stored magnetic energy in the motor phases is partially diverted to the dump capacitor.

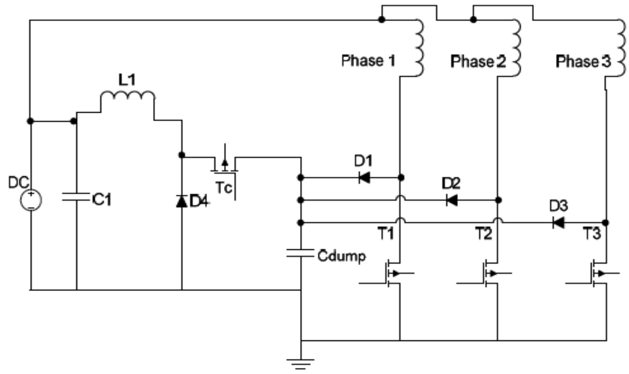

Figure 5.1: circuit of C-dump converter

During motoring operation and using hysteresis current control scheme, assume transistor T1 is turned on to energize phase 1. When the phase current exceeds the reference current, T1 is turned off and the diode D_1 is in forward bias. Now in this situation, the current charges the C-dump capacitor and so the voltage to increase across it. Then phase 1 current falls below the reference by Δi. At this time T1 is turned on to maintain the current at reference point. When the switch is closed the energy flows to C-dump partially. The remaining magnetic energy in the machine phase has been converted to mechanical energy. The advantage of this circuit is that there are minimum number of switches and independent phase control.

4.2 Conventional Converter Simulation and Modelling

This paper used MatLab simulink to simulate Bifilar and C-dump converters circuits.

A. Bifilar Converter Simulation

The simulation of bifilar converter is shown in fig. 6.1.

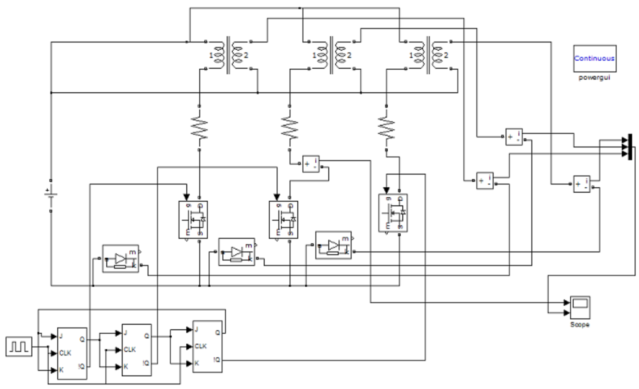

Figure 6.1: MatLab circuit of bifilar converter

The current of phase winding is shown in fig. 6.2.

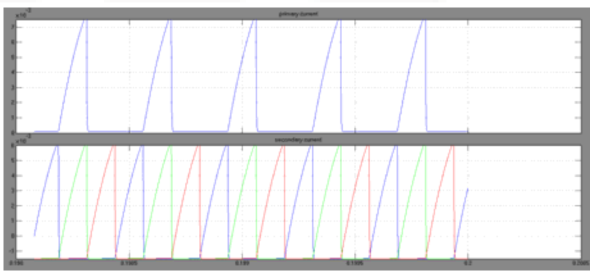

Figure 6.2: phase currents

As expected the current waveform for each phase is triangular. The current waveform of bifilar secondary winding for three phases which transfers the stored magnetic energy to the source is shown in fig. 6.2.

B. C-dump Converter Simulation

The simulation of the C-dump converter is shown in fig. 6.3.

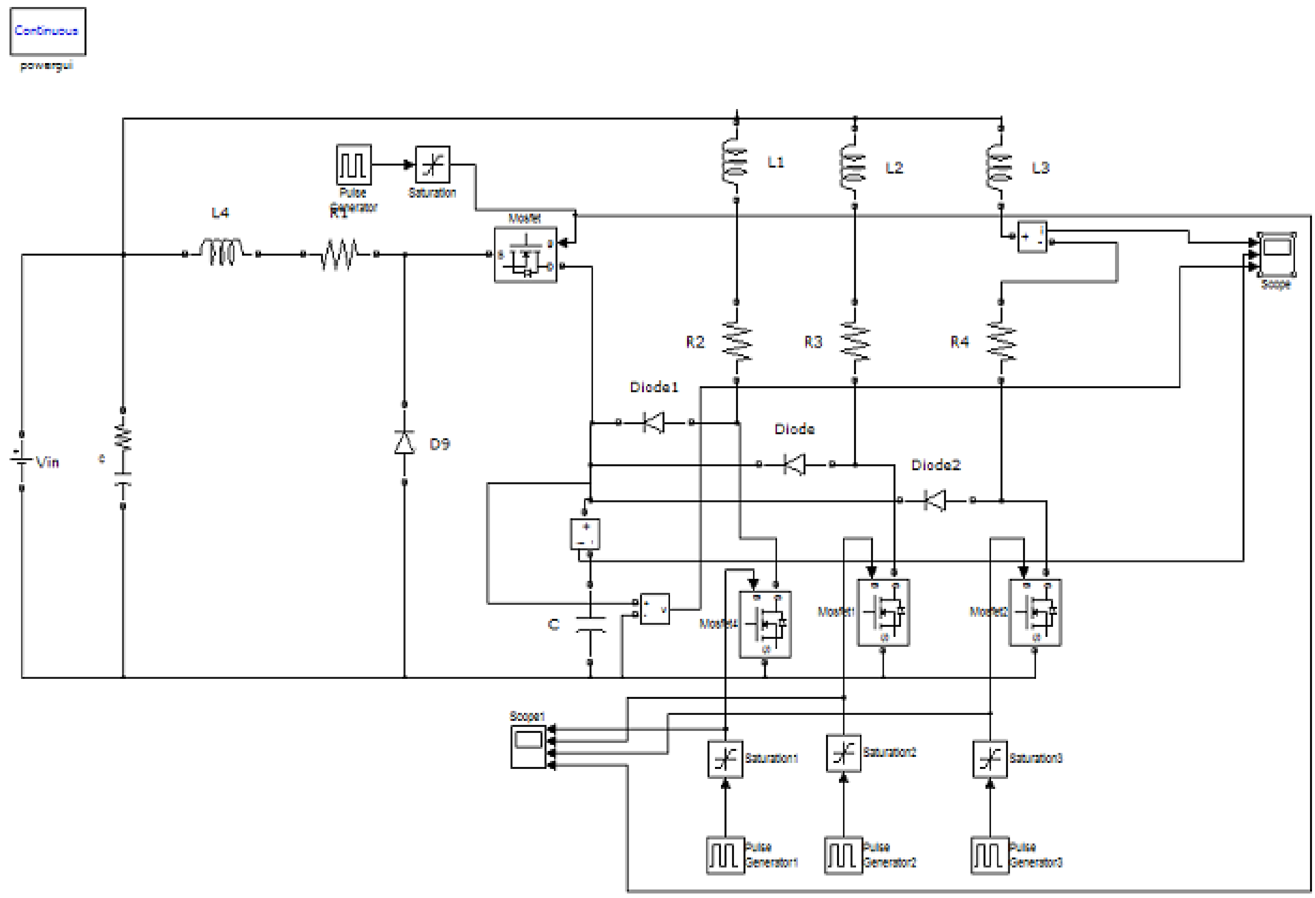

Figure 6.3: C-dump converter

The current of each phase is shown in fig. 6.4.

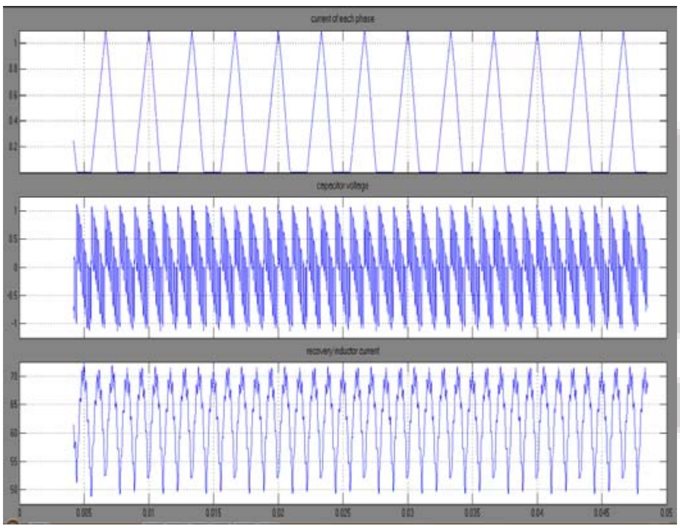

Figure 6.4: phase currents and capacitor current

The dump capacitor's voltage in this simulation is shown. Transferring energy from the dump capacitor to the recovery inductor has a sinusoidal waveform. The ripples on the sinusoidal waveform are because of dump capacitor's charging and discharging. When the chopper switch is on, the dump capacitor discharges and when it is off, the capacitor charges.

5. Introducing the New Topology Converter and its Simulation

The new topology introduced in this paper is a mixture of the two conventional topologies namely Bifilar and C-dump. A dump capacitor, a chopper and a recovery inductor and a diode have been added, so the energy that remains in the phases after turning off the phase switch, can be recovered to the source. Like the C-dump converter, the recovery energy from each phase stores in the dump capacitor through the freewheeling diodes and when the switch is on, the dump capacitor discharges through the recovery inductor to the dc source. The converter's circuit with the new topology is shown in fig. 7.1.

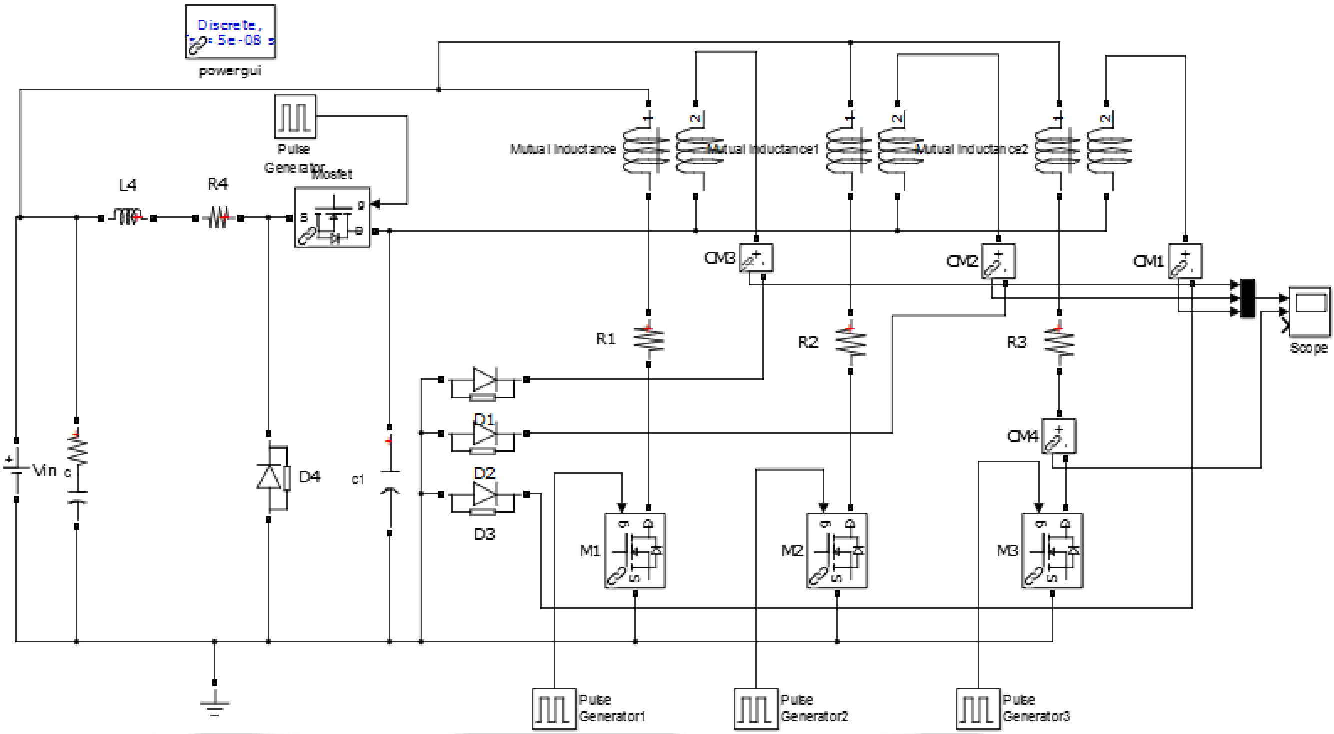

Figure 7.1: modified C-dump converter

The current waveform for the phase winding of each phase of the converter with the new topology is shown in fig. 7.2.

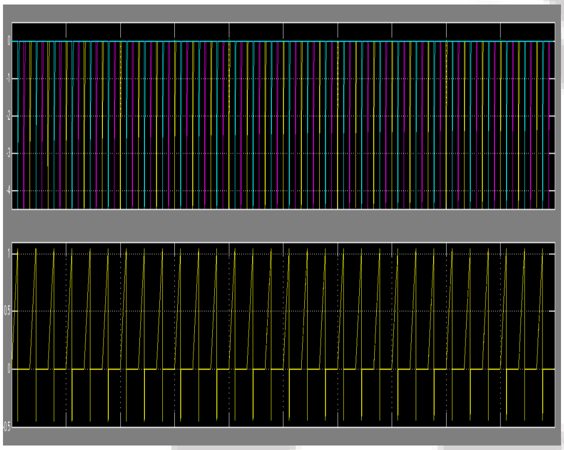

Figure 7.2: Phase Current

One of The main features can be compared with what was shown in Fig. 6.4 is the current waveform of the bifilar secondary winding of phases in the new topology. The width of the waveform in Fig. 7.2 is smaller than the width of the waveform shown in Fig. 6.4 which means that in the new topology, the bifilar secondary windings discharge by a faster rate. It can be seen that the width of each triangle is much less. It can help us to increase the rate of the switching in the converter with new topology and so we can have a higher rotational speed in a switched reluctance motor with bifilar windings.

6. Conclusion

The SR motor can drive in high speed with the modified C-dump converter. The discharging time of the secondary winding of the bifilar winding is reduced and so the speed is increased. Now a days we need more green energy. This paper also included with a green energy consumption which is reliable, long life and high efficiency. The future scope of this paper is the closed loop control of C-dump converter

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